EFFECTS OF PARALLEL MAGNETIC FIELD ON TRANSPORT PROPERTIES OF CARBON NANOTUBES

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Introduction

It has been shown previously that the controllable change of a carbon nanotube's (CNT) bandgap by axial magnetic field allows restoring the shape of the bands profile of the CNT device [1]. To calculate magnetoconductance (MC) of devices made in the configuration of a standard CNT field-effect transistor (CNFET) few assumptions were made about this shape. This allowed achieving a very good agreement between the experiment and the simulations in case of conduction channel formed by small-gap quasi-metallic single-walled CNTs (SWNT) contacted by Pd [1]. To further test these assumptions we measure three similar devices with conduction channel formed by metallic (M), quasi metallic (QM) and a semiconducting (SC) nanotube, contacted with Pd, Cr/Au and Pd electrodes respectively.

Experimental Results and Discussion

We measured the DC conductance as a function of the gate voltage G(Vg) at a small constant bias voltage (~1mV) under magnetic fields up to 33T at several temperatures. Magnetoconductance curves, shown in the figure, were obtained at the gate voltage Vg=Vg* (see the inset). For the magnetic fields above approximately 10T, an exponential magnetoresistance is observed $G \propto \exp(-\Delta(B)/k_BT)$ with linear $\Delta(B)$ dependence. Following [1] we concentrate on the coefficient $\alpha \equiv d\Delta(B)/dB$ and its ratio to the rate of the energy gap growth in the magnetic field $\lambda \equiv d\varepsilon_g/dB$ that are related to the shape of the bands profile.

Device 1. Slope of the MC curves point to $\alpha \approx 1.5$meV/T for all probed temperatures giving α/λ ratio of ~2.5 consistent with experimental results and calculations of [1] reported for a similar device, taking into account smaller SiO_2 thickness: 330 nm compared to 400nm in [1] that results in smaller α/λ ratio.

Device 2. Slope of the MC curves point to $\alpha \approx 1.2$meV/T for all probed temperatures giving α/λ ratio of ~1.5. As follows from [1] smaller α/λ ratio as compared to device 2 indicates smaller Schottky barrier height. This is qualitatively consistent with difference in work functions of palladium and chrome.

Device 3. Slope of the MC curves points to α increasing from 1.2 at 100K to 1.6 meV/T at 150 and 200K, giving the α/λ ratio of ~0.6. α/λ ratio in this case is much smaller compared to that for metallic and quasi-metallic CNTs. This indicates that minimum on the G(Vg) curve is reached when the Fermi level of the electrodes matches energy between the band edges of the CNT far from the electrodes. According to results of [1] that happens when the bandgap of the CNT is much larger than the temperature and is comparable to the height of the Schottky barrier for electrons Φ_B. Estimation of the band gap at B=0 from the diameter value is about 150meV, while the estimation of the barrier height is $\Phi_B \leq$ 400meV, which is work function difference of CNT and Pd.

References

 [1] Fedorov, G., et al., Nano Lett, **7(4)**, 960-964 (2007).
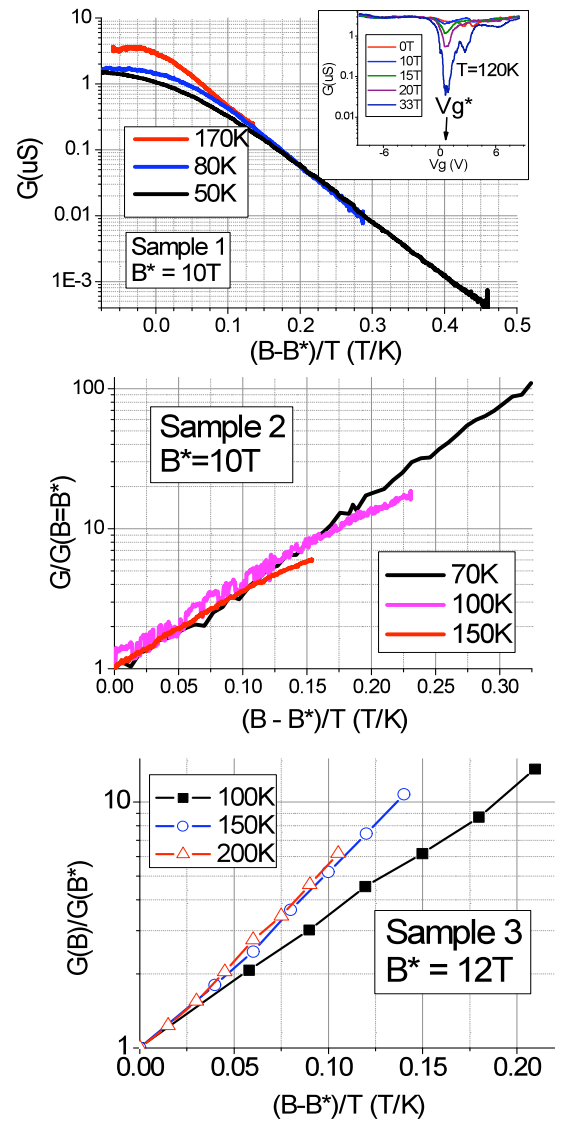
Magnetoconductance plots of three different devices with conduction channel formed by :
a) QM SWNT (d=1.6 ± 0.2 nm) contacted by Pd electrodes. Inset shows G(Vg) curves of this device at 120K. b) QM SWNT (d=1.9 ± 0.2 nm) contacted by Cr/Au electrodes. c) SC MWNT (d = 5.5 ± 0.5 nm) contacted by Pd electrodes.